AeroFoam

Polymer Science & Technology Laboratory
Cryogenics Test Laboratory
Kennedy Space Center

Advanced Materials and Processing Branch
Langley Research Center

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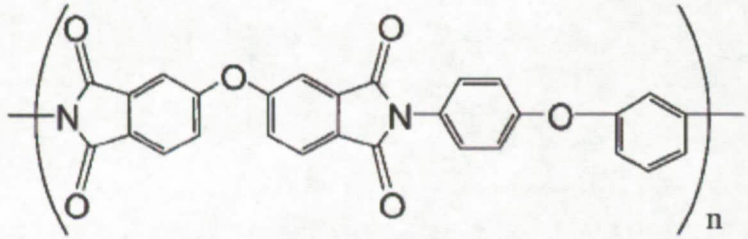
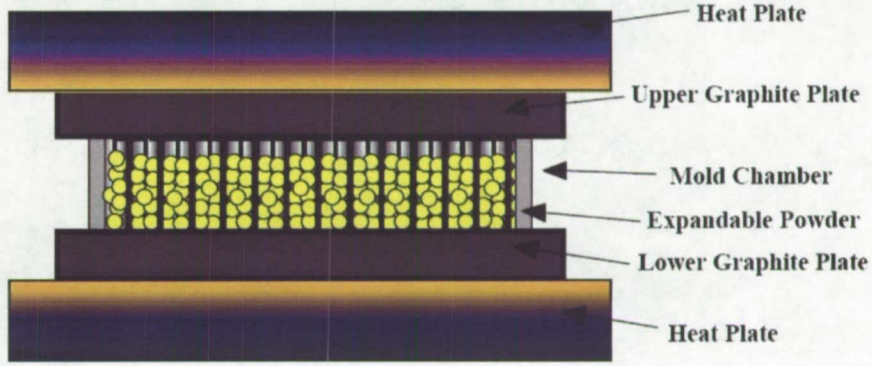
TEEK Polyimide Technology



TEEK-HH (0.082 g/cm^3) and TEEK-HL (0.032 g/cm^3), ODPA/3,4'-ODA

4,4'-oxydiphthalic anhydride /3,4'-oxydianiline



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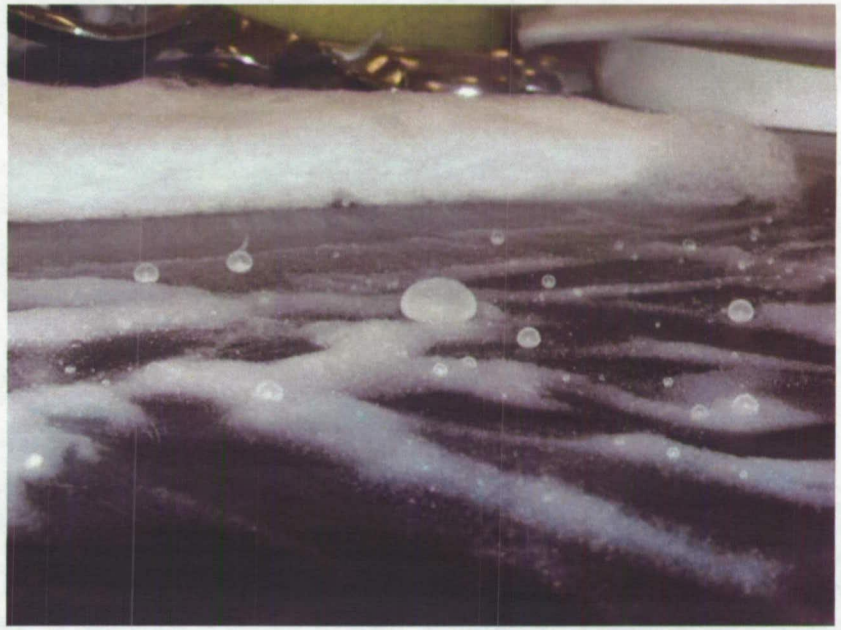
Aerogel Technology

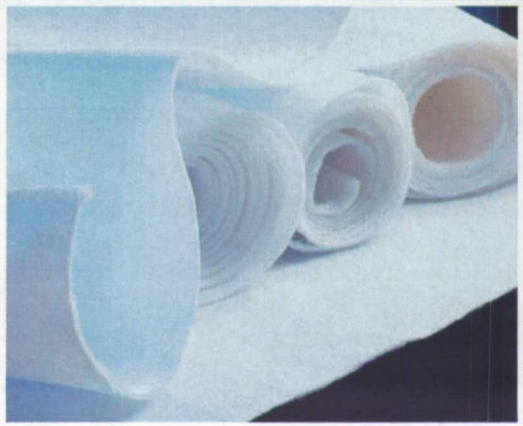
- Aerogel materials are generally silica based, light weight materials, fully breathable, and treated to be super-hydrophobic.

- Aerogel granules are free flowing, fills small cavities, does not compact, no preconditioning required, and can be molded or formed using binders.

- Aerogel granules (Nanogel®) by Cabot Corp.:
  - 90% porous with a mean pore diameter of 20 nm.
  - Bead bulk density ≈ 80 kg/m^3 (5 lbs/ft^3).
  - Individual beads are fragile (shear), but have high elastic compression of over 50% with no damage.
  - k-value ≈18 mW/m-K @ 25°C and 760 torr.
  - *www.cabot-corp.com/nanogel*

- Aerogel blanket (Spaceloft®) manufactured by Aspen Aerogels:
  - Bulk density 6 to 8 lbs/ft^3.
  - k-value ≈12 mW/m-K @ 38°C and 760 torr.
  - Use temperature range -273°C to 650°C (-459°F to 1200°F).
  - *http://www.aerogel.com/*





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Heat Flow in Foams

- Heat transfer in foams occurs by four mechanisms.
  - Conduction through cell struts and windows.
  - Gas conduction within cells.
  - Gas convection through cells.
  - Radiation through cells.

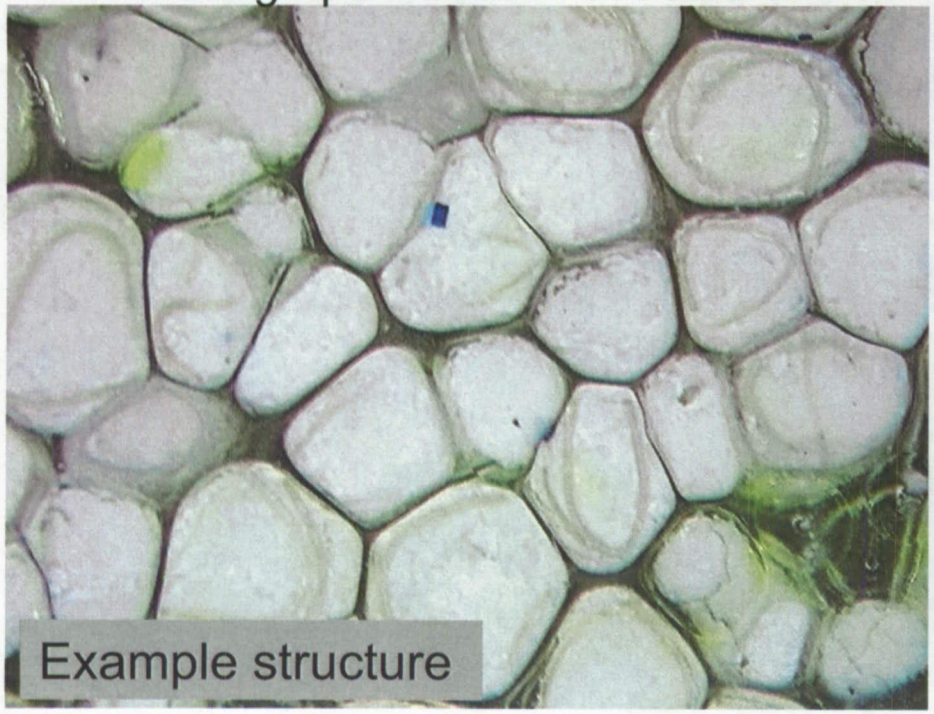
- Thermal conductivity in cellular solids.
  - When the blowing agent is a better insulator than air as gas exchange occurs over time thermal conductivity will increase.
  - Open cell foams typically have higher heat transfer in comparison to closed cell foams due primarily to convection.

- Factors affecting thermal performance include cell structure (density), foam composition, and cell content (open cell vs closed cell). The primary environmental factors include temperature, temperature difference, pressure (internal and external), and residual gas composition.

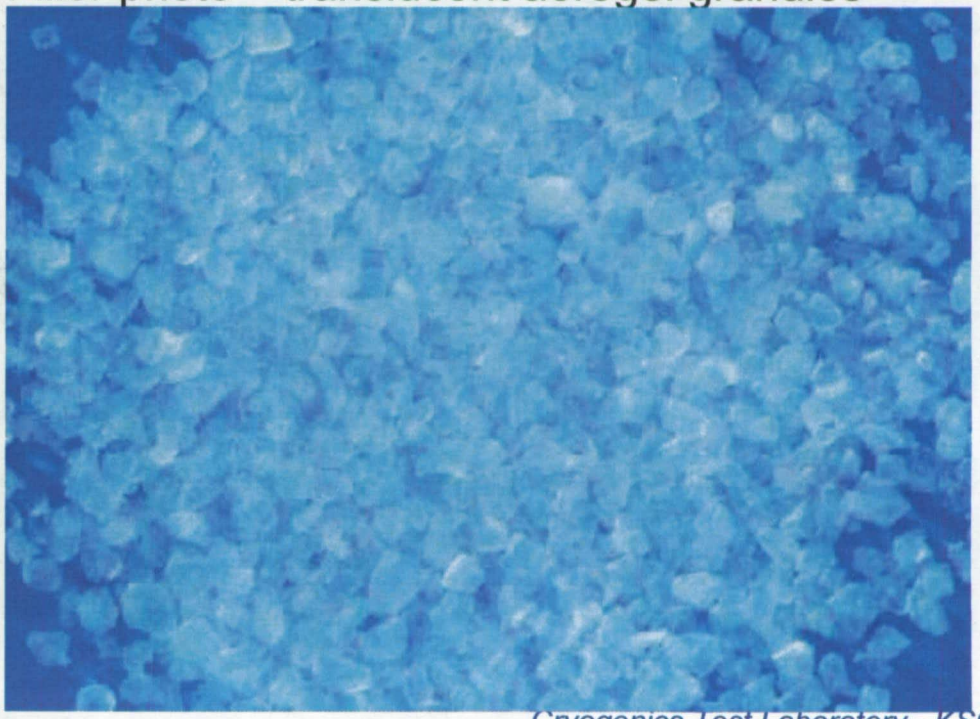
AeroFoam: what is it?

- AeroFoam is a composite material.
  - Component one is an organic polymeric cellular solid material.
  - Component two is an inorganic or organic aerogel or xerogel filler that is physically held in place by the "foam".
- The organic foam material strengthens the aerogel.
- The aerogel reduces the heat transfer within the foam.

Foam micrograph – cellular strucuture



Filler photo – translucent aerogel granules



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AeroFoam: what's the benefit?

- AeroFoam current examples are TEEK polyimide (PI) foam with Nanogel® beads/granules, TEEK PI foam with aerogel blanket from Aspen, and combinations thereof.

- Foam composites can be fabricated to target densities.
  - High density foam composites are considered as structural foams.
  - Low density foam composites are considered as flexible foams.

- Heat transfer is reduced – function of aerogel loading.
  - More aerogel added results in reduced heat transfer through foam composite.
  - Density affects on heat transfer are limited.
    - Higher density foams typically have higher heat transfer.
  - Aerogel loading is primary driver of heat transfer NOT density.
  - Aerogel blanket composites have most significant reduction in heat transfer.

- Improved acoustic insulation and vibration attenuation.

- TEEK foams and TEEK foam composites are inherently flame retardant.

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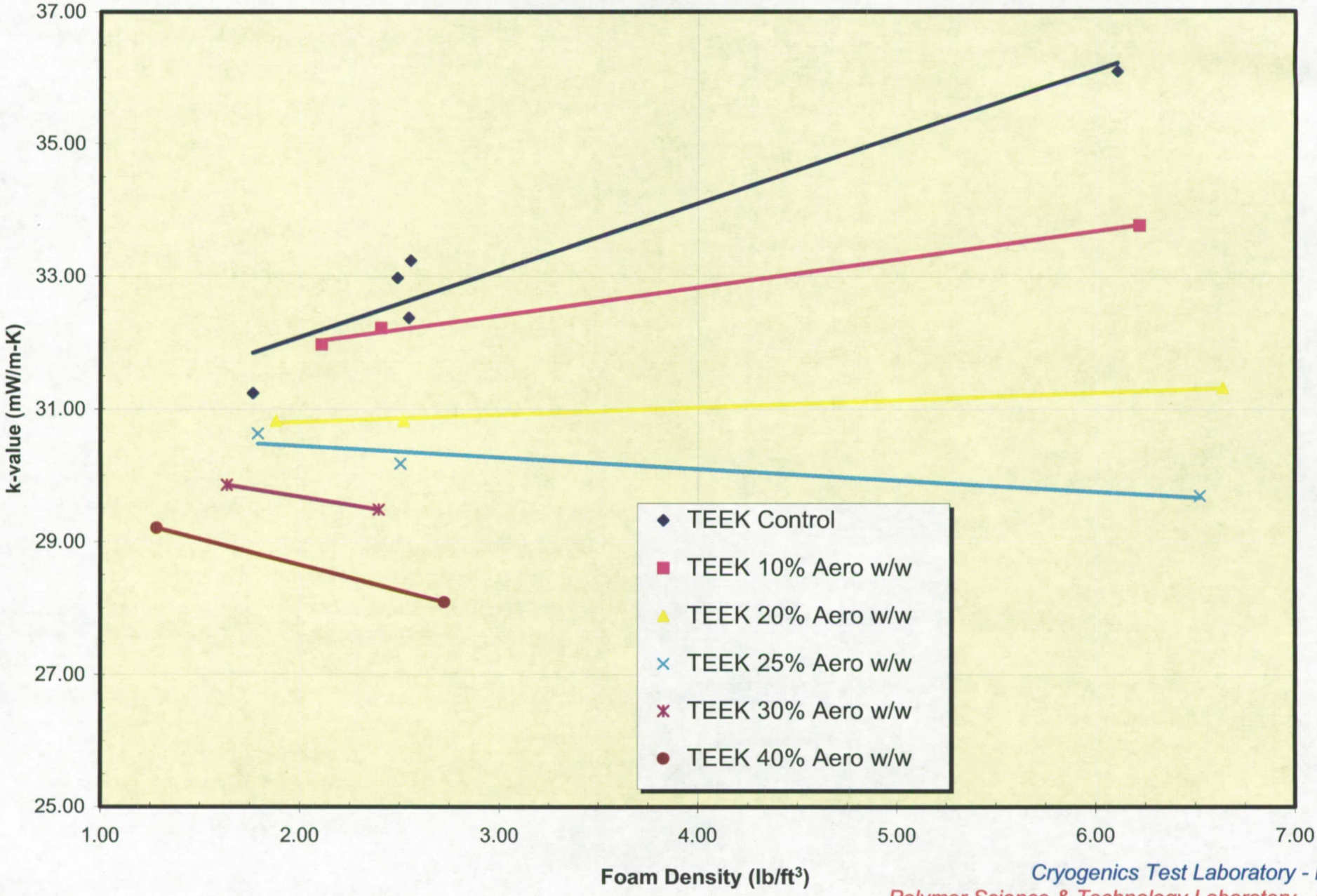
AeroFoam: Heat Transfer



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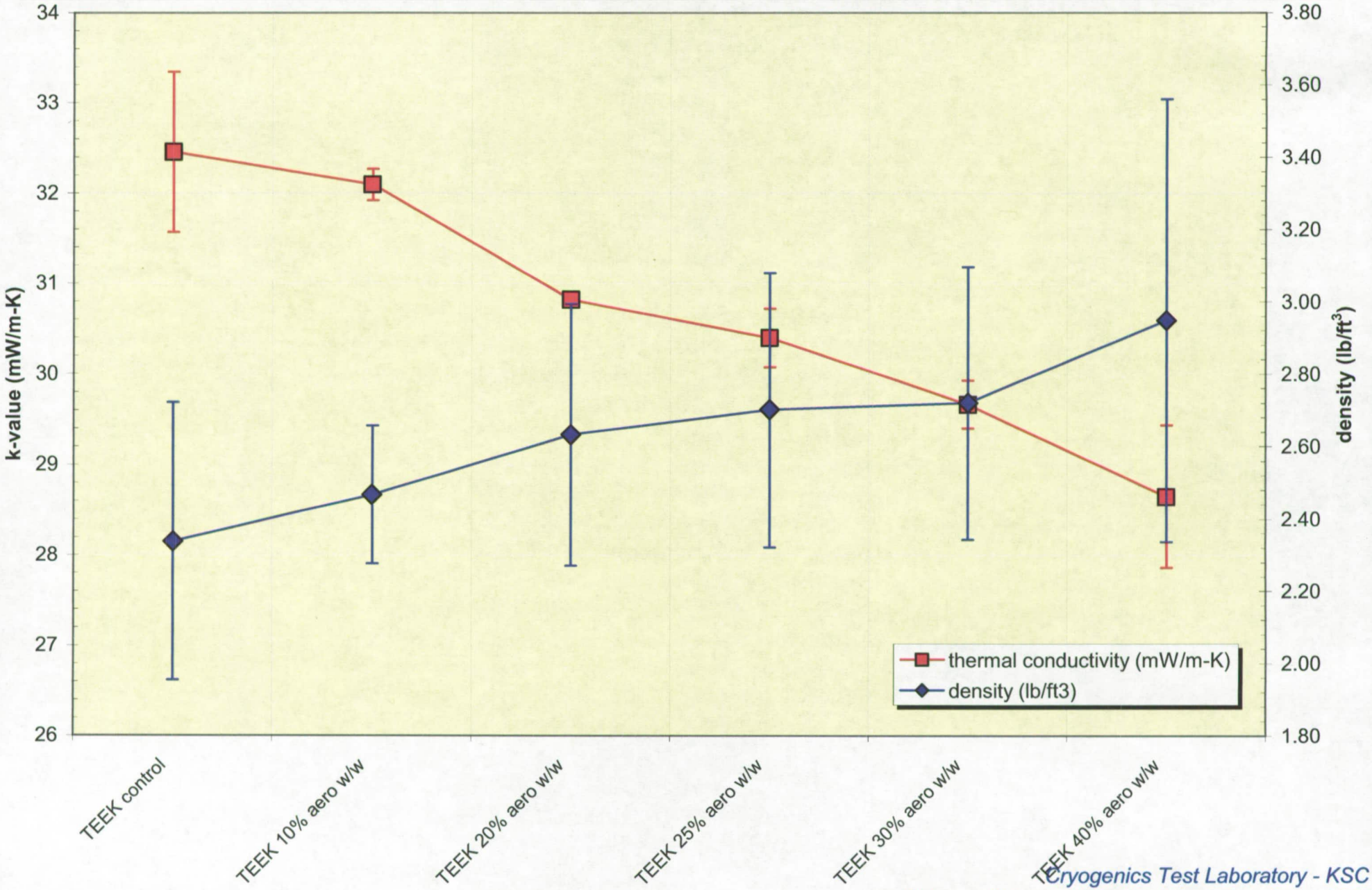
AeroFoam: Heat Transfer



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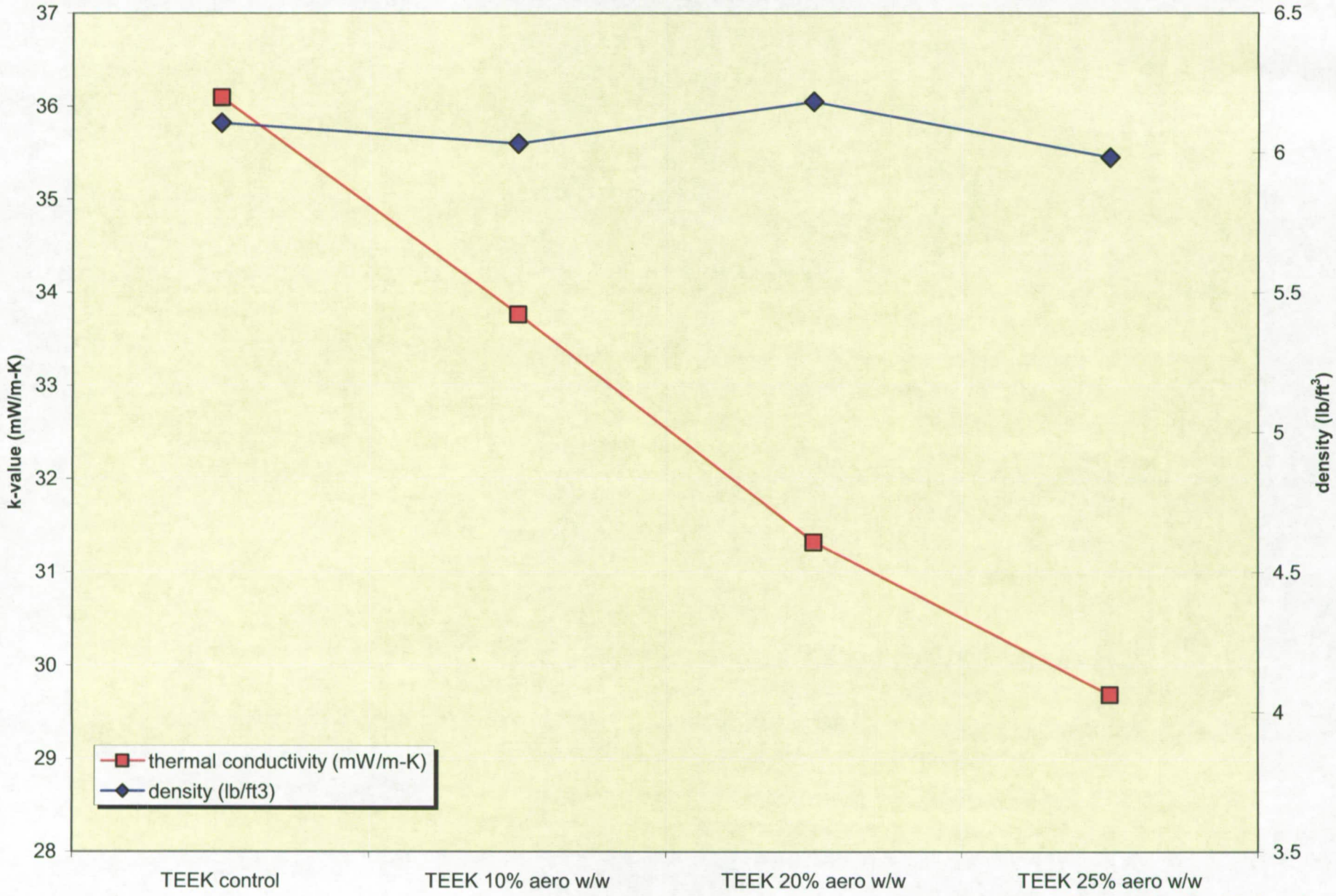
AeroFoam: Heat Transfer



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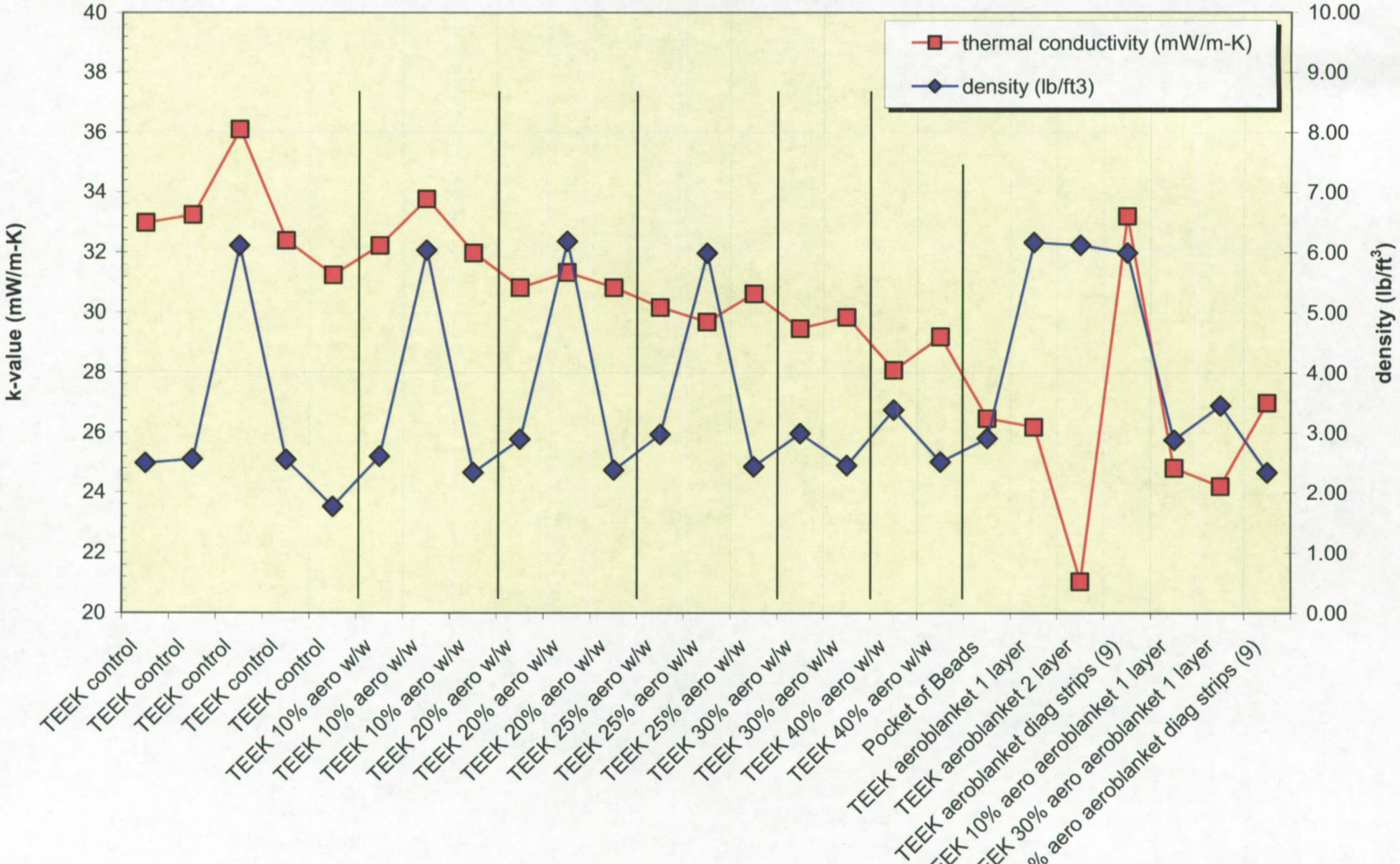
AeroFoam: Heat Transfer



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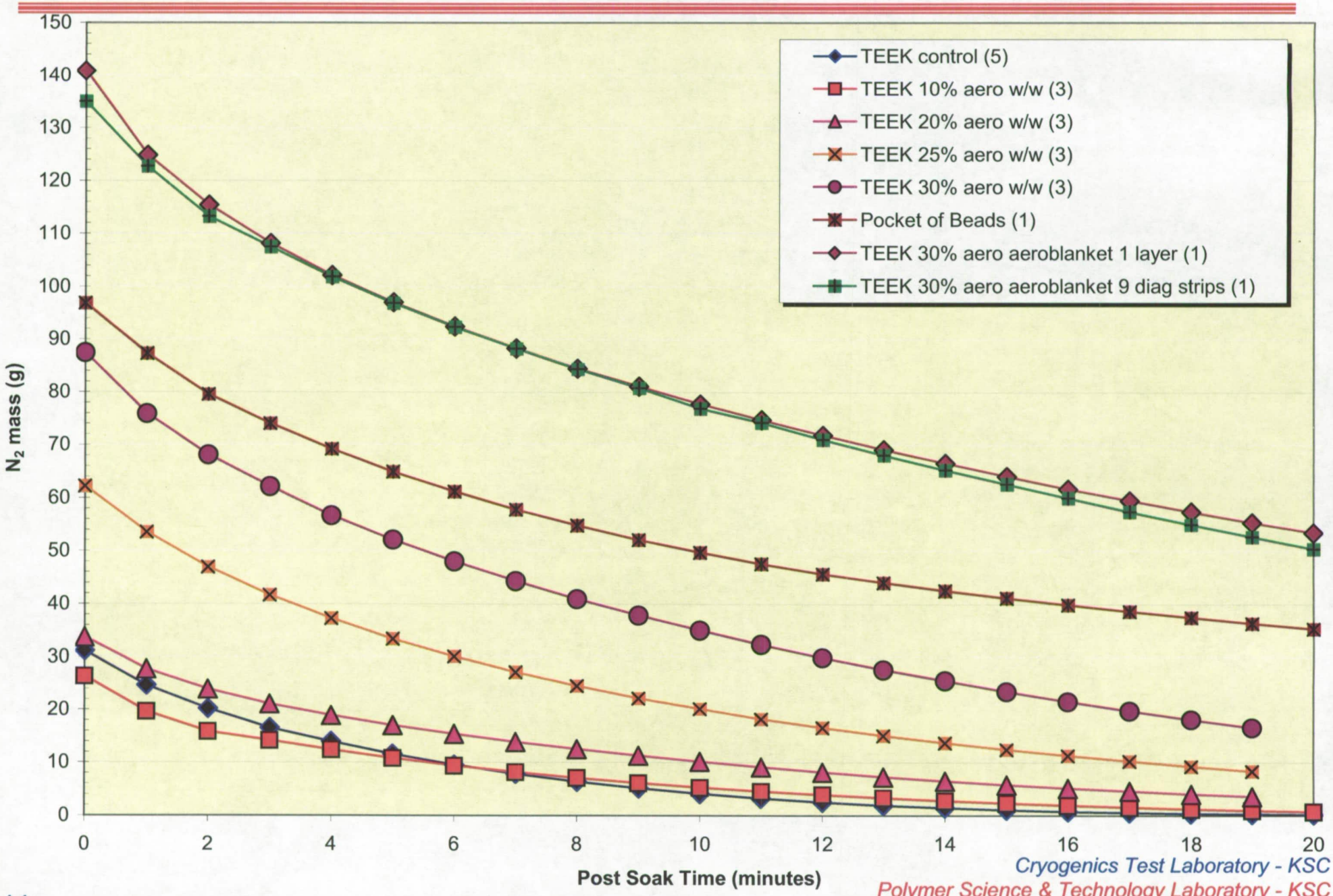
Aerofoam: Cryogen Storage



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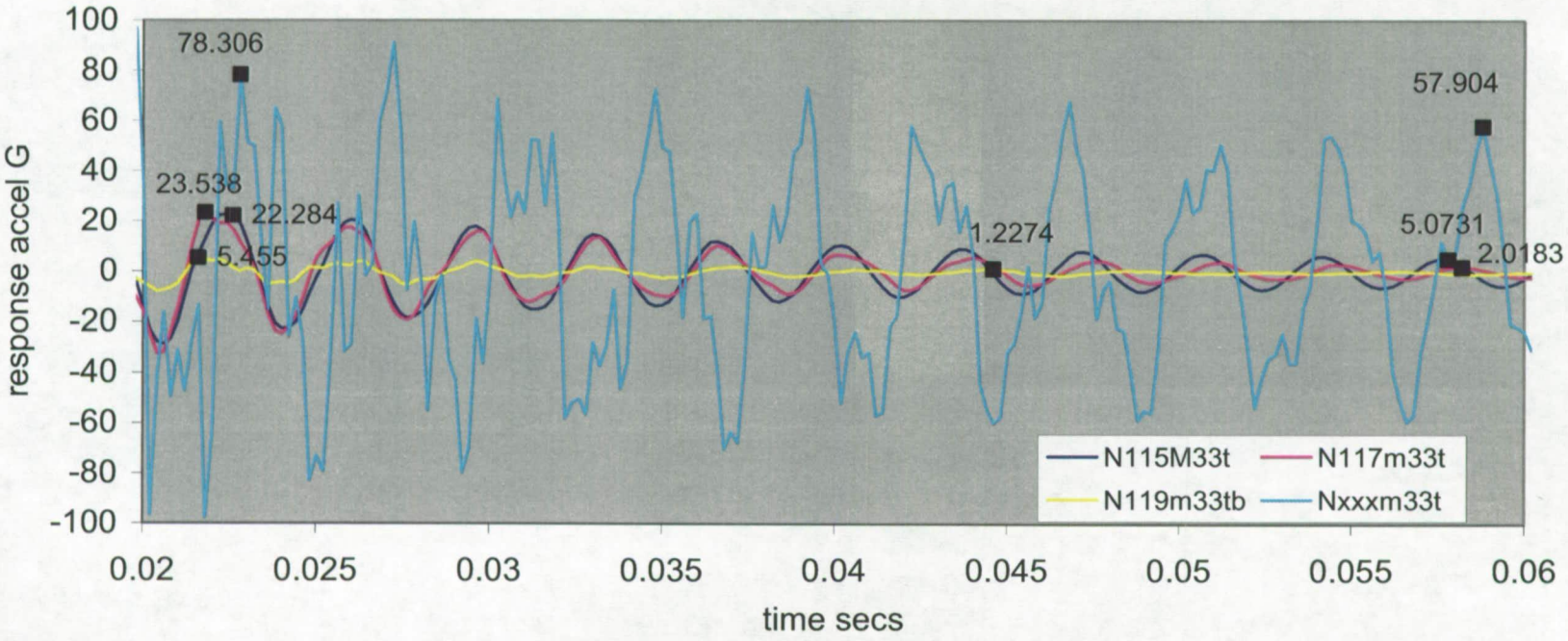
AeroFoam: Vibration Attenuation



Estimate of damping time series .02- .06 seconds from hammer hit

description	sample	high g	low g	cycles	log dec damping	Q
Teek	N115	22.3	5.07	10	0.080	
Aerogel single layer	N117	23.5	2.02	10	0.085	
Aerogel double layer	N119	5.45	1.23	6	-0.016	
AL Plate	Nxxx	78.3	57.9	9	0.240	

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AeroFoam: Conclusions

- AeroFoam can be made with several types of foams (some examples are).
  - Polyimide foams.
  - Polyurethane and Polyisocyanurate foams.
  - Silicone foams.
  - Polyolefin foams.

- AeroFoam composites reduce heat transfer - less insulation required - more weight saved.
  - Heat transfer is driven by aerogel loading NOT foam density.
  - Insulative and structural foams can reduce heat transfer by incorporating aerogel materials and forming a composite.

- AeroFoam composites have improved vibration attenuation properties.

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AeroFoam: Technology Transfer

- United States patent application filed.

- Several aerospace and materials companies have expressed interest in aerofoam materials and have signed Non-Disclosure Agreements.

- TEEK polyimide foam has been qualified for use on Naval Warships and TEEK aerogel composite materials could be readily qualified for Naval use.

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  - *Erik S. Weiser*

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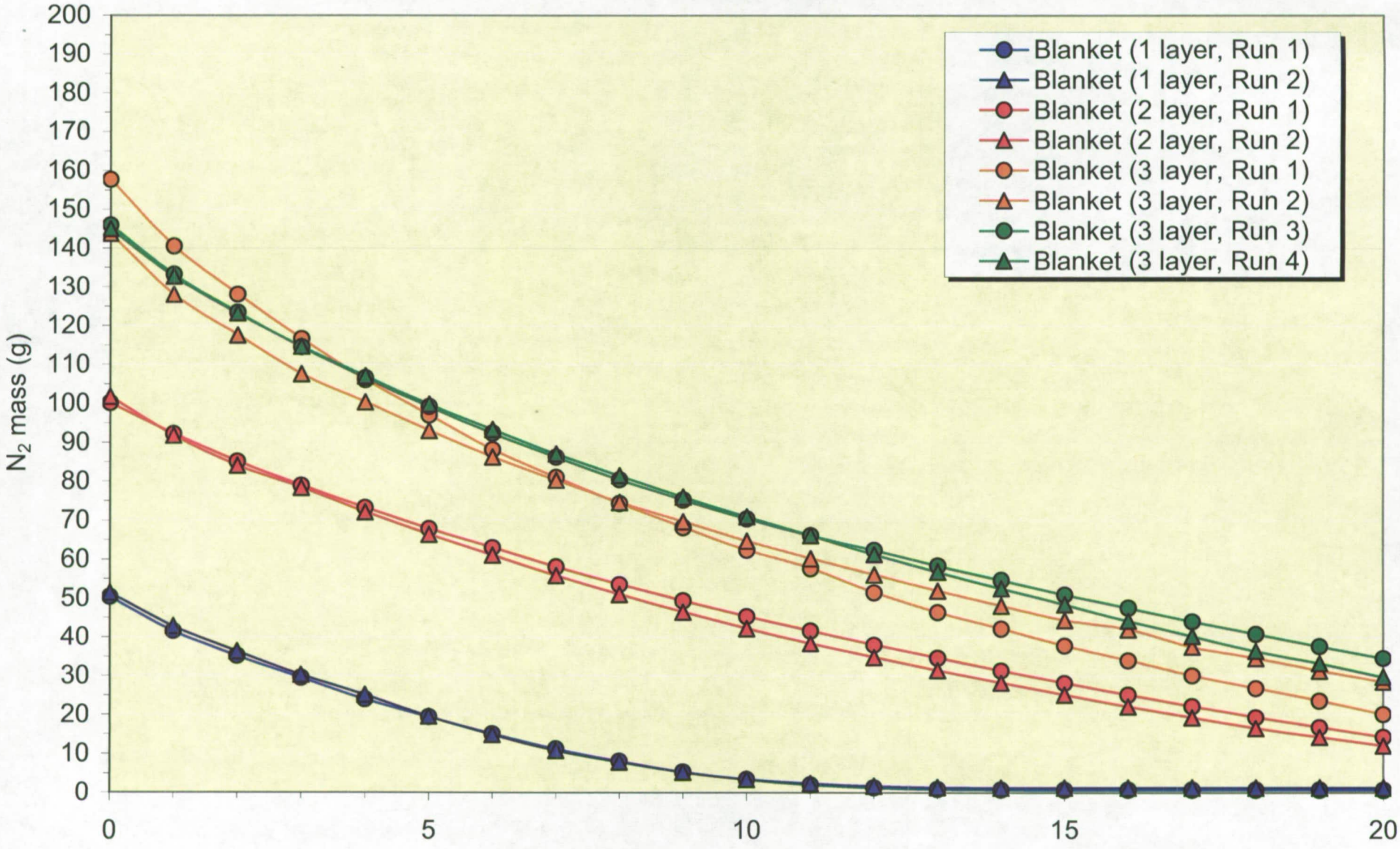
  - *Mark Velasco / Sierra Lobo*
  - *Phil D'Andreamatteo / Sierra Lobo*

- *Vibration attenuation measurements and analysis*
  - *Rudy Werlink / NASA*
  - *LaNetra Tate / NASA*

BACK UP SLIDES

Aerogel Blanket Cryogen Uptake and Storage



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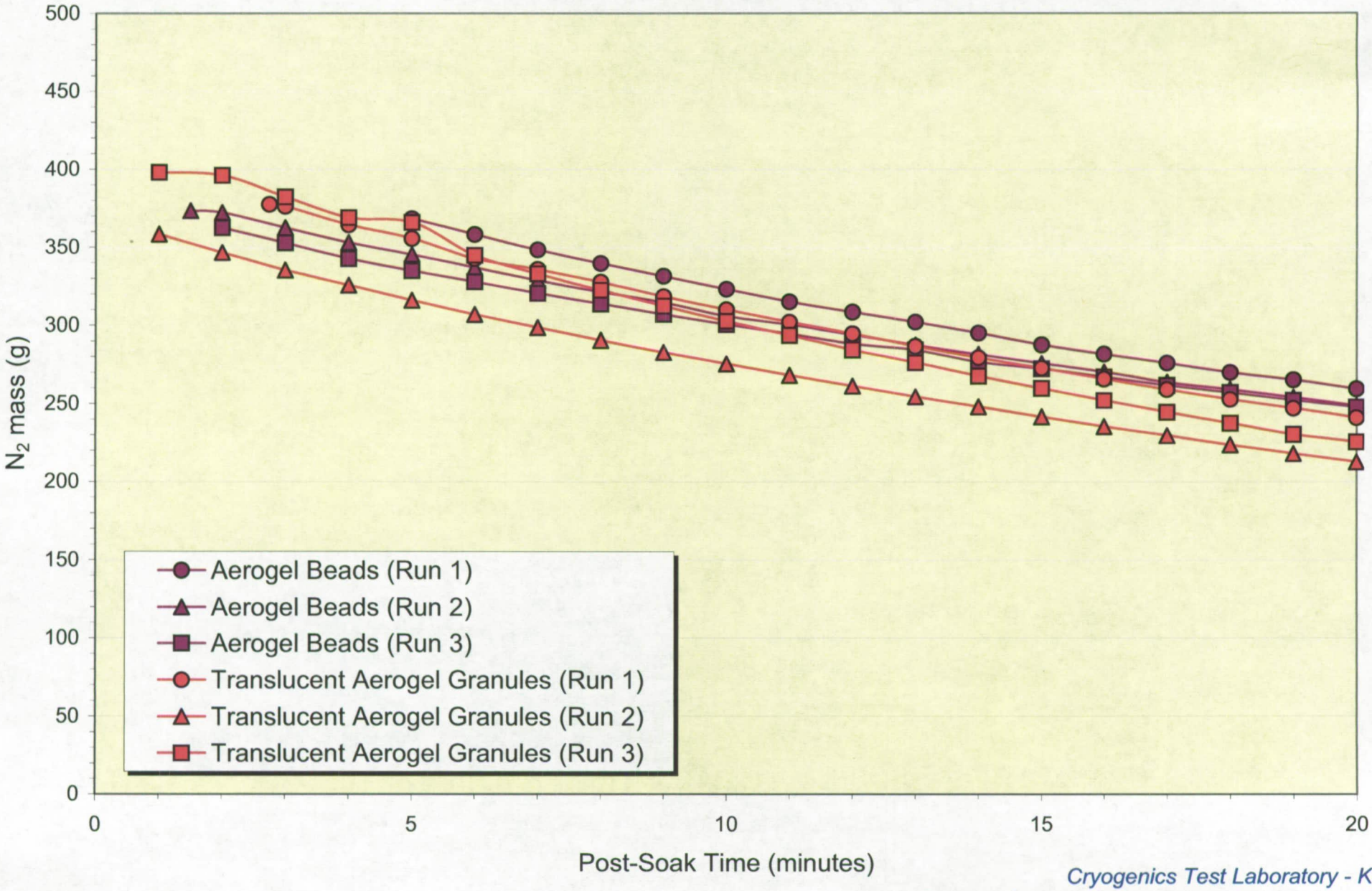
Aerogel Bead/Granule Cryogen Uptake and Storage



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